Development of a Waste Processing Incinerator for Life Support

John W. Fisher

As space missions become longer, waste treatment on a spacecraft transitions from storage to reclamation of items such as activated carbon and carbon dioxide (CO_2). Activated carbon and CO_2 can be reclaimed from hydrocarbon wastes such as paper, food scraps, and inedible plant biomass. Inedible plant biomass is produced when plants are grown in space to produce food. Growing plants consume CO_2, and burning the inedible parts of a plant produces CO_2 that can be used to grow more plants. Unfortunately the process of burning (combustion) produces some toxic byproducts. One of the objectives of Ames' research on waste processing is to develop technology to burn waste and reclaim CO_2 without releasing toxic materials into the spacecraft.

The combustion process generally does well at completely oxidizing biomass to CO_2 and water. This is obvious from observation of the results of a typical wood fire—only a small residue of inorganic substances, ash, is left in a fireplace after burning wood. The process of combustion of biomass in an incinerator operates in a similar way; the biomass is converted to gaseous products and inorganic ash. Combustion in a fireplace, however, typically takes place with wide fluctuations in temperature and composition as a function of time and position in the burning zone. Efficient combustors reduce the combustion fluctuation and achieve cleaner burning.

Fluidized combustion is a technology that provides good control of the combustion process and minimizes contaminants due to incomplete combustion. A fluidized bed consists of a bed of solid particles such as sand that behaves as a fluid. The fluidization occurs because a gas such as air is blowing up through the bed and causing the particles of the bed to float. Because sand is much denser than air, the bed holds much more heat energy than an equivalent amount of air. The heat energy held by the bed buffers the combustion process against the wide fluctuations in temperature that cause incomplete combustion.

Even in the best of combustors, however, some unoxidized material remains. In addition, some contaminants such as nitrogen and sulfur oxides are necessarily formed. In recent years, the research at Ames has focused on means to eliminate these byproducts. One approach has been to use reductive catalytic systems to convert the nitrogen and sulfur oxides to nitrogen and elemental sulfur—innocuous materials at room temperature. Oxidative catalysts can then oxidize the remaining hydrocarbon contaminants to very low levels.

In collaboration with university and corporate organizations, Ames has developed and tested an integrated incineration system that utilizes a fluidized bed combustor followed by a catalytic cleanup system. This system has demonstrated the ability to burn inedible biomass and produce a very clean CO_2 product. The concentration of contaminants in the gas exiting the incinerator is generally less than a few parts per million. Except for the CO_2 itself (toxic to humans at high concentrations), the exit stream from the incinerator will be able to meet the Space Maximum Allowable Contaminant (SMAC) standards for clean air in a spacecraft.

When this system has been optimized for reliability and energy efficiency, it will be ready for testing in an advanced life support system that "closes the loop" on carbon.

Carbon will travel in the system from plant to person to incinerator and back to the plant without ever becoming a stored waste.

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Development of the Vapor Phase Catalytic Ammonia Removal Process

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The Vapor Phase Catalytic Ammonia Removal (VPCAR) system technology represents the next generation in spaceflight water recovery systems. Water is the single largest resupply requirement associated with human space flight, accounting for 87% by mass of an astronaut's daily metabolic requirement. The VPCAR system achieves a mass metric almost an order of magnitude better than the current state-of-the-art water processors. (Mass metric is a technique used to compare candidate technologies by reducing all performance parameters into a single equivalent launch mass metric.) Incorporating the VPCAR technology into human space flight missions could potentially save hundreds of millions of dollars in resupply costs, depending on the specific mission scenario. As a result, a human-rated version of the VPCAR technology has been authorized for development.

The human-rated system is being developed under contract to Water Reuse Technology (NAS2-00089). This is an external contract for the development and testing of the next generation VPCAR technology. We are currently about 1/2 way through a two-year contracted development program. This activity is funded through Advanced Life Support program funds and a NASA peer reviewed NRA (00-HEDS-01).

Process Description. The VPCAR process is a two-step distillation-based water processor. The current configuration of the technology is shown in Figure 1. A process flow diagram is

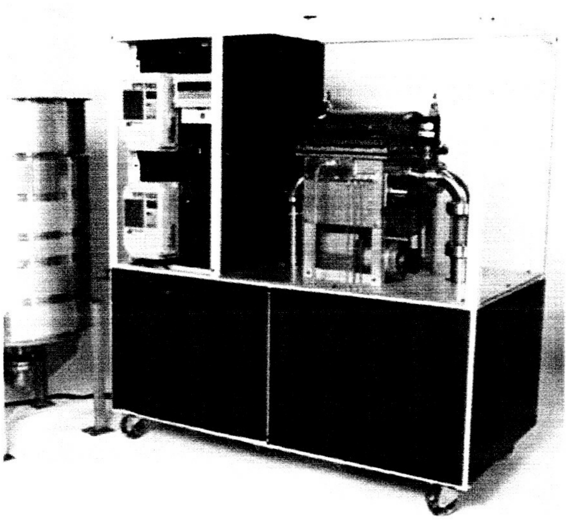

Fig. 1. Vapor Phase Catalytic Ammonia Removal (VPCAR) water recycling system.